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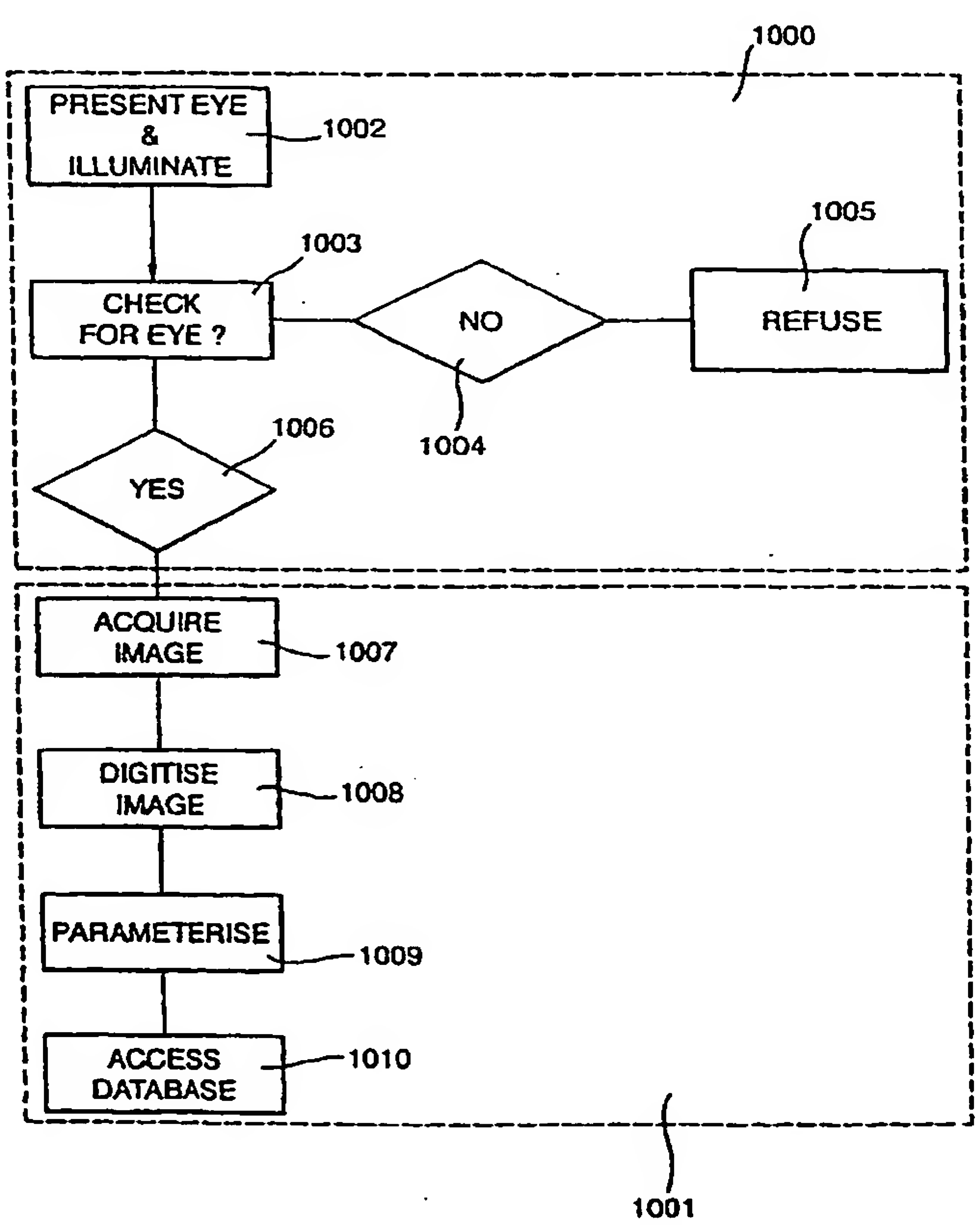
(54) Title: PERSONAL IDENTIFICATION



(57) Abstract: It is established that the iris of a person is characteristic and equipment is available for deriving recognition parameters from an image of an iris. Iris recognition (1001) is reliable provided that the test object is an eye but there is a danger of inappropriate results when test equipment is offered an object which is not an eye, e.g. a patterned contact lens. This invention performs supplementary tests (1000) adapted to distinguish between a real eye and an object purporting to be an eye. Supplementary tests include: (a) Illuminating the test object with polarised light and observing the orthogonal polarisation. A simple test measures the intensity of the orthogonal polarisation. A low intensity implies that the test object is not an eye. A more complicated test comprises forming an image with the orthogonal polarisation. A real eye gives a distinctive pattern similar to a Maltese cross. (b) Measuring the intensity of light returned along the direction of illumination. A low intensity implies that the test object is not an eye. (c) Projecting an image of a test pattern onto a test pattern onto a test object purporting to be an eye. The distortion of the image implies that the test object is not an eye.

WO 01/01329 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

PERSONAL IDENTIFICATION

This invention relates to personal identification and, more particularly, to apparatus and methods for use in personal identification.

There are many circumstances in which it is necessary for a person's identity to be checked or confirmed. This can, of course, be achieved by one human recognising another and this is the traditional method in many commercial and social environments. For example, doorkeepers can be employed to recognise person who should be admitted (and to reject others). Commercial enterprises such as banks and retail establishments employ staff who can recognise customers and provide or withhold services as appropriate. While these techniques provide commercially valuable acknowledgement of customers, they are not always applicable. Many commercial enterprises have a large clientele and the numbers are so large that no human staff would know all the clientele. Furthermore, it may be necessary to provide a service at unsociable hours and the employment of human staff would not be appropriate. The use of documents, e.g. passports, is well established as an aid to identification, but the documents can be lost and, therefore, other techniques are desirable.

The use of transaction cards, e.g. credit cards, is common place but the cards do not identify their owners and extra security checks are necessary. The usual check is a personal identification number (PIN) but users have to remember their PIN and more secure techniques would be desirable. A person might also be identified using biometrics. This usually involves obtaining, and preferably encoding, the biometrics from a person and storing the results in, for example, a database. Recognition includes establishing the same biometrics on a person presenting for identification and comparing the measured biometrics with those stored in the database. A match is taken as establishing the identity of the person. For the purposes of this specification a "biometric" is a statistical or quantitative measure of a biological feature of a person.

Recently, the use of biometrics based on optical observation of an eye have been proposed for identification purposes. US patent specification number 5,291,560 published 1 March 1994 describes a method of encoding an optical image of an iris into a 256-byte code. It has been shown that such a code can be a very reliable personal identifier.

Although the identification techniques are very effective, there is a potential problem in that the recognition procedure may not, in fact, be carried out on a real eye but on an object purporting to be an eye for the purposes of recognition. Clearly, the possibility of a "non-eye" raises the possibility that the identification could be invalidated in certain circumstance.

This invention reduces the possibility of this error by modifying the registration stage of the recognition process. More particularly, the recognition process includes extra tests to confirm that the object presented for recognition is an eye and not an object purporting to be an eye. It would be desirable to ensure that only eyes can be registered and the inclusion of the extra tests mentioned above reduces the risk of registering a "non-eye".

It is now convenient to indicate some of the circumstances in which a non-eye might be presented for registration into a database for use in personal recognition techniques based upon the measurement of eye biometrics.

Contact Lenses

The wearing of contact lenses to ameliorate vision deficiencies is widespread. There will be refraction for vision correction but this does not affect the recognition parameters sufficiently to jeopardise the recognition process. However, humans also wear contact lenses in order to modify or enhance their appearance. In this specification, contact lenses which are intended to have this effect will be known as "cosmetic contact lenses". In order to achieve its effect a cosmetic contact lens is usually patterned in order to provide the desired change of appearance. A cosmetic contact lens may also be functional in that it ameliorates vision defects but the colouring or patterning is an essential feature of a cosmetic contact lens. Under these circumstances, the eye recognition process may respond to the contact lenses, and more particularly to the pattern on the contact lens, instead of the eye itself. Thus the "biometrics" which are measured may refer to the contact lens and not to the eye.

Since cosmetic contact lenses are used to a significant extent, there is a risk that an eye recognition technique could be prejudiced. A particularly serious possibility arises from the fact that cosmetic contact lenses can be mass-produced and many different humans could be wearing similar or even identical cosmetic contact lenses. It is therefore possible that a potential user could present for registration wearing cosmetic contact lenses. This gives rise to a strong possibility that the registration would record the contact lens rather than the customer. If many individuals wear the same contact lenses they may become indistinguishable and thereby cause considerable confusion with many recognition failures. Furthermore, there is a risk that a customer who registers in patterned contact lenses would become unrecognisable when the contact lenses are removed.

Because cosmetic contact lenses are a source of potential difficulties, it is desirable to warn users and potential users that cosmetic contact lenses should not be worn for purposes of eye recognition. In case a potential user ignores this warning, it is desirable to carry out tests to indicate the presence of cosmetic contact lenses. Where a human supervisor is present, it is appropriate to inform the human supervisor in the first instance and allow the human supervisor to provide a tactful explanation to the customer or potential customer.

False Eyes

In some cases, persons who have lost an eye, wear a false eye to improve appearance. Clearly, it is highly desirable that such a false eye shall look as real as possible and there is a possibility that a false eye could be registered with a recognition system. As it is undesirable to register cosmetic contact lenses, it is also undesirable to register false eyes should these be presented. Tests designed to recognise a real eye from a "non-eye" should prevent the registration of false eyes and, therefore, prevent the recognition of persons by virtue of a false eye.

Criminal Deception

It is also possible that criminals might attempt to register deceptive artefacts (such as photographs) with a view to carrying out fraudulent transactions based upon false recognitions. If criminals were to succeed in registering an artefact which is not an eye then any patterns which form the basis of recognition would become recorded in the database. Therefore, in recognition, the same artefact would give

rise to the same recognition pattern which, since it is in the database, would give rise to an inappropriate recognition. Effective supervision of the registration process should prevent such fraudulent attempts but, especially if they work in collusion with registration staff, criminals might succeed in registering a "non-eye". If the registration process includes effective techniques for recognising a "non-eye" then such criminal activities would be made considerably more difficult. It is suggested that it is best to deal with such matters at the outset by refusing to make an inappropriate registration.

Commercially available apparatus for carrying out optical eye recognition comprises a camera and a light source. The camera includes a lens which forms an image of part of the eye using radiation provided by the light source. The image on the screen is conveniently divided into units, e.g. pixels, and the intensity of radiation is measured in each unit. These primary measurements may be converted into a set of recognition parameters using techniques described in US patent number 5,291,560 dated 1 March 1994. The preferred number of recognition parameters is 256-bytes On registration of a new candidate, the values of the recognition parameters are recorded in a database together with whatever personal information is considered appropriate for the candidate. On recognition, the values of the same set of recognition parameters are produced and compared with the database. If the two sets of values are sufficiently similar, identification is taken as established.

The invention supplements the established recognition parameters as mentioned above by further measurements intended to establish that a test object is in fact an eye rather than a "non-eye" e.g. a cosmetic contact lens. The eye recognition tests should be carried out at the registration stage so as to avoid recording identification parameters relating to a non-eye.

According to a preferred embodiment of the invention, the test for a non-eye may also be carried out at the recognition stage. If the recognition data indicates that the test object is a non-eye, recognition would be refused without necessarily attempting to match the data acquired with the database.

Three techniques which are considered particularly suitable for distinguishing between an eye and a non-eye will now be described. These techniques are conveniently identified as "Corneal-Cross", "Linear Illumination" and "Red Eye". It is

also possible to carry out tests intended to recognise specific cosmetic contact lenses which are widely used.

Corneal-Cross (Polarised Light)

The use of polarised light for eye classification tests depends upon the fact that an eye is an anisotropic medium which changes some of the incident light into the orthogonal polarisation. Most objects only change the polarisation to a slight extent and, therefore, the presence of the orthogonal polarisation is an indication that the object is an eye rather than, for example, a photograph. A simple test merely measures the intensity of the orthogonal polarisation and accepts the eye if a threshold is exceeded.

A more complicated test depends upon the fact that a distinctive pattern, often known as a "Corneal Cross", can be observed in an image formed from the orthogonal polarisation. The pattern of a "Corneal Cross" resembles the pattern usually known as a "Maltese Cross". Detection of this pattern is a good indication that the target object is an eye.

The requirement for cross-polarisation is conveniently implemented by locating a polarisation filter across the light source and a similar filter oriented at right angles at the lens of the camera.

Red Eye

An eye also has the property of returning light along the path from whence it came irrespective of the orientation of the path relative to the eye. Therefore, illuminating an eye by radiation substantially parallel to the axis of the test equipment results in reception of a signal which is also parallel to the axis of the equipment. Measuring the strength of this returned signal therefore discriminates between an eye and an object such as a photograph which lacks the directional properties of an eye. Measuring the strength of the returned radiation above a threshold is a convenient way of making a distinction.

Linear Illumination

Many of the established techniques for personal recognition based on the capture of eye biometrics use a uniform field of illumination. This is appropriate since the technique intends to form an image of part of the eye. However, if the illumination is non-uniform, e.g. comprising its own distinctive pattern such as a straight line or several parallel straight lines, the image will indicate whether or not a

flat surface or a curved surface is under observation. If the observed surface is flat, the image will consist of one or more straight lines corresponding to the source. If the observed surface is curved, the pattern of illumination will be distorted. For example, straight lines will become curved lines. If a candidate is wearing patterned contact lenses the illuminated surface will be the curved surface of the lens. If no contact lenses are worn (or if the contact lenses are transparent) the iris will be illuminated and this is a substantially flat surface. Therefore, a different pattern will be achieved. It is, therefore, possible to detect whether or not the candidate is wearing patterned contact lenses which conceal the features of the eye.

This invention can provide different levels of security depending on the cost and complexity of equipment. For example, a relatively small number of registration points may be needed to serve a large number of recognition points. Thus the registration points could be relatively complicated and expensive whereas the recognition points could be less complicated and, therefore, cheaper. The invention will now be described by way of example with reference to the accompanying drawings.

Figure 1 is a flow sheet illustrating the method as a whole;

Figure 2 is a part of Figure 1 illustrating eye recognition;

Figure 3 illustrates apparatus for testing an eye using polarised light;

Figure 4 is a flow sheet illustrating a method corresponding to the apparatus of Figure 3;

Figure 5 illustrates apparatus for carrying out eye recognition tests;

Figure 6 illustrates an illumination source for use in the apparatus shown in Figure 5.

Figure 7 illustrates the illumination of an eye and a contact lens with parallel lines; and

Figure 8 is a flow sheet illustrating the registration of contact lenses.

Figure 1 illustrates the method of carrying out eye recognition in accordance with the invention. The method comprises two major sections namely, classification test 1000 which is adapted to distinguish between a real eye and an object purporting to be an eye. For example, classification test 1000 is adapted to distinguish between a contact lens and an eye.

In addition to the classification test 1000 the procedure also comprises recognition sequence 1001. This is a well-known sequence for identifying an individual by means of optical tests performed on an eye of said individual. It should be noted that the tests usually recognise the difference between the right and the left eye of an individual and the sequence 1001 is, therefore, specific to a particular eye. The recognition sequence described in US patent 5291560 (dated 1 March 1994) is particularly suitable.

The classification test 1000 comprises presentation 1002 in which a candidate places a selected eye near the test equipment and initiating the test, e.g. by pressing a "start" button. Illumination is provided and this allows check 1003 to be performed. If check 1003 gives the result "no" in box 1004 then refusal 1005 becomes effective.

If the result of check 1003 is that recognition 1006 is granted, then the results of recognition sequence 1001 are taken into account. It has already been stated that box 1001 constitutes a conventional eye recognition sequence and this comprises the steps of acquiring 1007 an optical image and digitising 1008 said optical image. Conveniently the camera comprises a facetted screen with one facet for each pixel of the image. The intensity of light on each facet is recorded whereby a digital image in pixels is achieved. The digital image acquired in step 1008 is parameterised using the techniques described in US patent 5291560. The parameters are characteristic of a particular eye and, therefore obtaining the parameters effectively constitutes identification of the eye presented at step 1002. Having obtained the characteristic parameters a database is accessed is step 1010. On registration of a new candidate (and more specifically on registration of a specific eye of a new candidate) the acquired parameters are stored in the database together with an appropriate identification of the subject. In the case of recognition the acquired parameters are matched against parameters already existing in the database and a match constitutes recognition of the subject. As has already been stated the recognition sequence 1001 is conventional and known to persons skilled in art of eye identification.

The optical tests 1000 and 1001 may be carried out simultaneously (if possible) or in any order. The computation analysis is carried out, of course, after the relevant

optical tests have been performed. However, there is an important requirement in that on activating refusal 1005, the subject is refused recognition or registration whatever the other results may be.

Figure 1 also illustrates, at the generic level, apparatus used to carry out the methods of the invention. The apparatus comprises a first subsystem 1001 for capturing recognition parameters and a second subsystem 1000. For recognising the difference between an eye and an object purporting to be an eye. The first subsystem 1001 includes a camera 1007,1009 for capturing the recognition parameters. (A commercially available system identified as "Iriscan 2100 series" is suitable for use as the camera 1007,1008) The second subsystem 1000 includes a detector 1003 responsive to the difference between the response from an eye and an object purporting to be an eye. Details of apparatus are illustrated in Figures 3, 5, and 6.

Figure 2 shows in greater detail a sequence comprised in classification test 1000 and giving greater detail of check 1003.

The initial step comprises projecting 1020 characteristic radiation onto a test object, e.g. an eye presented for identification. The result of projection 1020 is that a (possibly modified) version of the characteristic radiation 1020 is returned and this is acquired in step 1021. The characteristics projected in step 1020 are, of course, known and the acquired return 1021 is compared with the expectation. If the expected match is not achieved then recognition is refused as described in boxes 1004 and 1005 of Figure 1. If the expected correspondence is achieved then the process of Figure 1 continues as indicated in boxes 1006 and 1001.

The apparatus illustrated in Figure 3 observes an eye using polarised light and, effectively, crossed polarisation filters. Under these conditions of illumination a "real eye" gives distinctive results. If these results are observed, the recognition of box 1001 is accepted. If the expected results are not observed, it is assumed that the object is not an eye and recognition is refused.

The apparatus illustrated in Figure 3 comprises a conventional eye recognition camera or a detector 15 (together with its associated computerised circuitry and software). If a camera is used, it is monochrome and it is sensitive in the visible and infrared part of the spectrum.

A polarisation filter 11 is placed in front of the camera/detector 15. In particular, the polarisation filter 11 is a cube beam splitter which reflects one polarisation of wavelengths in the range 560 - 730nm while transmitting the same wavelength in the orthogonal polarisation. At wavelengths outside the stated band (560-730nm) the cube treats both polarisations substantially the same and, more specifically, it transmits both polarisations.

The illumination source is a lamp 12 which has a wavelength centred on 670nm. In other words, the spectrum of the lamp 12 is chosen so that it is inside the range 560-730nm. This arrangement has the effect that one polarisation produced by the lamp 12 passes directly through the polarisation filter 11 to emerge along the path 13. This polarisation is not utilised in the test. The orthogonal polarisation is reflected by the filter 11 along the path 14 to illuminate an eye generally indicated by the numeral 100. The eye 100 returns light along the path 14 and back to the polarisation filter 11. On its return journey, one polarisation is reflected back to the lamp 12 whereas the orthogonal polarisation is transmitted to the camera or detector 15. In addition to the lamp 12 the apparatus comprises a second lamp or lamps 16 but its spectral range is outside the range 560-730nm. The polarisation filter 11 is not effective at these wavelengths and both polarisations are transmitted to the camera 15 for normal eye recognition. LED's are suitable for use as the lamps.

The apparatus shown in Figure 3 can be used to carry out two similar tests. Figure 4a is a flow sheet which illustrates a simple test based upon threshold whereas Figure 4b is a flow sheet which illustrates a more complicated test based on pattern recognition. Those parts of the two tests which are the same will be described first.

On presentation of an eye for identification the activation step 1041 is performed and the source 12 is switched on. It is convenient to use an unpolarised source 12 and the second step therefore comprises polarisation 1042 so as to select polarised light for the test. Illumination step 1043 illuminates the eye under test with polarised light and light is returned from the eye. Because a real eye affects the polarisation of light the returned illumination does not have the same polarisation as was imposed in the step 1042. In cross polarisation step 1044 only the orthogonal polarisation is accepted.

In the simple test, illustrated in Figure 4a, the cross polarisation 1044 impinges on a sensor 15 which detects a level of illumination. An eye changes the polarisation of incident light and, therefore, there will be a substantial level of cross polarisation 1044. In the case of an object such as a photograph, the polarisation of incident light is not substantially affected and, therefore, the level of cross polarisation 1044 is low. The setting of a threshold for detector 15 therefore discriminates between a real eye and a possible fake such as a photograph.

In the more complicated test, illustrated in Figure 4b, the orthogonal polarisation 1044 is formed into an image 1045 which displays a pattern typical of an eye, i.e. a "Corneal Cross" because it resembles a shape usually known as a "Maltese Cross". Forming the "Corneal Cross on the screen of a camera 15 allows the pattern to be detected 1046 and this is taken as the distinction between an eye and a non-eye.

There are a plurality of techniques which can be used to recognise the image. First, the image can be displayed on a visual display unit and viewed by a human supervisor. It is easy for a human supervisor to recognise the difference and take appropriate action, e.g. to issue a tactful message "please remove your contact lens". Computerised pattern recognition techniques can also be used to recognise the difference.

It is the purpose of a cosmetic contact lens to hide the cornea of an eye and, therefore, it is to be expected that wearing a cosmetic contact lens will degrade a "Corneal Cross" to the extent that it is not recognisable.

Figure 5 illustrates apparatus which can be used to observe an eye. Similar apparatus is commercially available from Iriscan Inc. In Figure 5, the apparatus is generally indicated by the numeral 10 and it comprises a light case 25 which prevents stray radiation affecting the recognition. This light case 25 contains a camera 21 which is associated with software for performing the algorithm described in US patent 5291560. The light case 25 also contains an illumination unit 22 for illuminating an eye 100. The light case 25 also contains a mirror 23 which has the property of reflecting some incident radiation and transmitting the remainder. A display 24, which comprises an image of the eye 100 provided by the camera 21, is located behind the mirror 23. With the illumination unit 22 switched on, the eye 100 is illuminated so that, after reflection by the mirror 23 an image of the eye is

captured in the camera 21 and this image is used for conventional eye recognition. In addition, the eye 100 can see through the mirror 23 to a display 24. It enables the eye to locate itself in the correct position for observation. Camera 21 is fixed focus and the eye 100 is placed at the correct position so that it is in focus.

The mirror 23 reflects some radiation and transmits other radiation. This can be achieved by partial silvering to give whatever ratio of reflection to transmission is desired. Alternatively, mirror 23 reflects near infrared and transmits visible light. The visible light is, of course, used by the eye to position itself whereas the near infrared (which cannot be seen by the eye 100) is used for recognition.

To use the apparatus, the customer presses the start switch (not shown) which activates all equipment. The camera operates at 20-30 frames a second so that moving the eye can change the display 24 so that the eye becomes correctly positioned. A focus assessment algorithm selects frames for processing. Conveniently, the focus assessment algorithm selects frames which are in focus.

In conventional apparatus 10, the illumination unit 22 comprises a single lamp which provides whatever wavelengths are used for recognition. According to one embodiment of the invention, illuminator unit 22 is adapted to carry out eye classification tests (1000 of Figure 1) as well as recognition tests (1001 of Figure 1). This illumination unit 22 is shown in greater detail in Figure 6.

The unit generally indicated by the numeral 30, comprises a light source 31 for carrying out conventional eye recognition and "red eye" tests and a secondary light source 32 for carrying out tests based upon an image of parallel straight lines.

The primary light source 31 comprises a bulb 33 with a reflector 35 to give a slightly diverging beam which illuminates an eye 100 via path 42. Some of the light provided along path 42 is returned to the Camera 21 via the mirror 23 and this light is used for conventional eye recognition.

In addition, primary source 31 utilises a known property of an eye, namely that an eye returns incident light back along the same path. Thus, the eye 100 returns some of the light back along path 42 to the mirror 37 and this light is reflected onto the photodiodes 38. The photodiodes 38 detect whether or not his returned light is above or below threshold. If the light is above threshold it is assumed that the object 100 is indeed an eye and recognition will proceed. If the returned light is below threshold it is assumed that the object 100 is not an eye, e.g.

a photograph or some other fake, and recognition is refused (the effect is similar to the well known "red eye" effect observed in flash photographs.

It is emphasised that this technique uses the same light source 31, namely lamp 33, for both eye recognition and classification. Therefore, both tests can be carried out at the same time.

The secondary light source 32 comprises a lamp 34 and a reflector 36. The light from the lamp 34 also passes through a filter 39 to reduce the intensity of visible light but the filter 39 is provided with opaque parallel bars 40 so that there is a pattern. This pattern is focussed on the eye 100 by means of the lens 41 and the pattern can be observed by the camera 21.

In the case of a real eye, the image projected on the iris will comprise parallel straight lines whereas a curved contact lens will give an image of curved lines. The difference between these two images can be recognised and hence the equipment will refuse to acknowledge an eye wearing reflective contact lenses. The difference can be recognised by a human operator looking at an image displayed on a video display unit or it can be recognised using computerised pattern recognition techniques.

The distinction between the two cases is further explained with reference to Figure 7. Figure 7a illustrates a pattern projected onto a real eye 100a. The eye comprises an iris 101a and the pattern 102b is reflected from flat tissue within the eye. This has the effect that the pattern of parallel straight lines is returned to camera 21.

Figure 7b shows an eye 100b which is wearing a contact lens 101b and the pattern is therefore projected onto a curved surface 102b. This distorts the pattern so that the distinction between a real eye and a contact lens can be observed at the camera.

This sequence can be described with reference to Figure 2. In this case box 1020 comprises projecting a pattern of parallel lines onto an eye (or other test target). In the case of a real eye the acquired pattern 1021 is also parallel straight lines and detection of this pattern in box 1022 allows continuation 1001. If the pattern of lines is bent or distorted then recognition is refused is accordance with boxes 1004 and 1005.

It is also possible to utilise the standard recognition software to increase the chances of rejecting cosmetic contact lenses. Organisations wishing to use eye recognition to obtain specimens of contact lenses which are available to the public. The patterns of these lenses can be registered in the system and, if a candidate for recognition (or for registration) presents one of these registered patterns, registration or acceptance can be refused. (A message indicating "please remove your contact lenses" would be an appropriate response.)

The method will be described with reference to Figure 8 which is a flow sheet of the method. As illustrated in Figure 8, a lens for registration is mounted on a support which has the same radius of curvature as an eye, e.g. providing a neutral background for the lens.

The mounted lens is presented in step 1081 to registration equipment and the pattern of the lens is registered in step 1082 using the conventional registration algorithms. After registration the lens is re-oriented in step 1083. Reorientation comprises rotating the lens about its axis. For example, the lens is rotated through 45° and re-registered in step 1082. Steps 1082 and 1983 are repeated 1034 several times. For a rotation of 45° it is appropriate to repeat the sequence 8 times. Recording the lens in several orientations has the effect that should a candidate present for recognition or registration when wearing the lens the lens will be recognised and registration or recognition would be refused. This method is effective for candidates who wear commercially available lenses but, should a new lens become available, the method is inapplicable because the new lens will not be recorded in the system.

As can be seen from Figure 1, the method according to the invention requires at least two tests, namely classification test 1000 and a recognition test 1001. Clearly, it is appropriate to ensure that both tests are carried out on the same target or test object. Furthermore, if several classification tests 1000 are carried out, it is appropriate to make sure that all of the tests are carried out on the same target. According to the present invention, the plurality of tests can be carried out in a short time, e.g. substantially less than one second. This makes it very difficult to use different targets for different tests. Furthermore, the "red-eye" test and recognition are carried out with the same illumination but using different sensors. This means that the "red-eye" test and recognition are achieved simultaneously.

This makes it impossible to use different targets for two tests. Even when a plurality of tests are used in rapid succession, it is desirable that the tests can be randomised which makes it difficult to provide different targets for the different tests. Furthermore, the testing comprises an optical sequence in which data is captured followed by the analysis of the data. Depending upon the security requirements different operational strategies are possible. Where it is desired to minimise the incident of false recognition (at the risk of false rejection), recognition should be refused if any one or more of the test give satisfactory results. Where false recognitions can be accepted to avoid false rejection it is more appropriate to use an algorithm which combines the results of different optical tests to reconcile conflicting results. The algorithm has the effect of combining a plurality of optical tests into, effectively, a single test. A simple algorithm would take a majority verdict. Furthermore, recognition should be refused is any one or more tests give unsatisfactory results.

In order to confirm the potential problems caused by the wearing of contact lenses, three different contact lenses were subjected to test. The test comprised individuals who were registered in the system without contact lenses also registering with contact lenses.

Three different forms of contact lens were tested as follows.

LENS 1

This was a "cats eye" contact lens which was a plain yellow opaque lens with a black painted slit.

LENS 2

Two different specimens of a deep blue "fantasy" lens were utilised. These comprised deep blue patterns overwritten on a clear background.

LENS 3

These were brown "natural" lenses tinted in two tones which are designed to enhance the appearance of a brown eye.

In normal recognition right and left eyes give different patterns and, therefore, normal registration is specific to a right eye or a left eye.

Tests carried out with lens 1 generally failed to give any recognition. The lens was too different from a normal eye to be accepted into the system. Since

registration was consistently refused, this extreme form of cosmetic lens is unlikely to cause problems.

The use of lens 2 gave rise to inconsistent results. The subject was enrolled without any contact lenses and the subject was further enrolled wearing lens 2. When the subject wore no lens, recognition was always correct. When the blue lens were worn, sometimes the subject was correctly recognised and sometimes the blue lens was recognised. In some tests, the blue lens was recognised even when worn on the wrong eye. Furthermore, the two different specimens were confused with one another. This establishes a degree of confusion which would not be acceptable in an operational system and, therefore, these tests indicate the desirability of recognising cosmetic contact lenses.

Similar confusing results were obtained using lens 3.

It is believed that inconsistent results are obtained because blinking can cause slight displacement of the contact lenses. In some placements the subject is recognised whereas in other placements the contact lens is recognised. This further illustrates the desirability of recognising contact lenses and refusing enrolment or recognition to subjects wearing contact lenses.

CLAIMS

1. A method for performing an identification procedure on a test object which purports to be an eye of a human candidate, which method comprises carrying out on said test object one or more optical classification tests [1000] adapted to distinguish between an eye and a non-eye.

2. A method according to claim 1, wherein the procedure is carried out for the purpose of registering recognition parameters of said eye in a data base [1010] and said registration is refused [1004] when said optical classification test or any one of said optical classification tests fails to classify the test object as an eye.

3. A method according to claim 2, wherein, when said optical classification test or all of said optical classification tests classify the test object as an eye [1006], and the method also comprises:-

   (i) forming an image of part of said eye [1007],
   (ii) capturing [1009] recognition parameters of said image, and
   (iii) storing [1010] said parameters in a data base.

4. A method according to claim 1, wherein the procedure is carried out on a test object purporting to be an eye of a candidate for the purpose of matching recognition parameters [1010] of said eye with recognition parameters stored in a data base and said matching is refused when said optical classification test [1000] or any one of said optical classification [1000] tests fails [1004,1005] to classify the test object as an eye.

5. A method according to claim 4, wherein, when said optical classification test or all of said optical classification tests classify [1006] said object as an eye the recognition procedure also comprises:-

   (i) forming an image of part of said eye[1007],
   (ii) capturing [1009] recognition parameters of said image, and
   (iii) matching [1010] the captured parameters with parameters in a data base.

6. A method according to any one of the preceding claims, in which the optical classification tests [1000] include illuminating [1041] a test object purporting to be an eye with polarised light [1042] and observing [1045] the orthogonal polarisation [1044] returned from the test object.

7. A method according to claim 6, wherein the observing includes measuring [1045] the intensity of the returned orthogonal polarisation and accepting the test object as an eye when the observed intensity [1046] is above a threshold and rejecting the observed object as an eye when the intensity is below the threshold.

8. A method according to claim 6, wherein the observing includes forming [1045] an image from the returned orthogonal polarisation and accepting [1046] the test object as an eye when the image includes a corneal cross and rejecting the observed object as an eye when the image does not include a corneal cross.

9. A method according to any one of the preceding claims, wherein the optical classification tests comprise illuminating from a first direction [1020] a test object which purports to be an eye and measuring the intensity of radiation returned from said object in a direction opposite to said first direction [1021] and accepting the test object as an eye when said intensity is above a threshold and rejecting the test object as an eye when the intensity is below said threshold.

10. A method according to any one the preceding claims, wherein the optical classification tests comprise forming an image of a test pattern [1020] on the test object, observing said image [1021] and accepting the test object as an eye when the image matches [1022] the test pattern and rejecting the test object as an eye when the image does match the test pattern.

11. A method according to any one of the preceding claims, which comprises registering [1081] recognition parameters of undesirable objects in the database of a recognition system and refusing recognition to any test object wherein the parameters of the test object match parameters of an undesirable object.

12. Apparatus for carrying out a method according to any one of claims 1 to 10 which apparatus comprises first [1001] and second [1000] subsystems wherein said first subsystem [1001] includes a camera [1007,1009] for capturing recognition parameters of a test object and said second subsystem a detector [1003] responsive to features which distinguish an eye from an object purporting to be an eye.

13. A apparatus according to claim 12, in which second subsystem [1000] includes a light source [11,12] for illuminating with polarised light a test object purporting to be an eye and the detector [15] is responsive to the orthogonal polarisation returned from the test object.

14. A apparatus according to either claim 12 or claim 13, wherein the detector [15] is adapted to measure the intensity of the returned orthogonal polarisation and to accept the test object as an eye when the observed intensity is above a threshold and to reject the observed object as an eye when the intensity is below the threshold.

15. A apparatus according to claim 12, wherein said detector [15] takes the form of a camera [15] for forming an image from the returned orthogonal polarisation..

16. A apparatus according to any one of claims 12 - 15, wherein the said second subsystem [1000] comprises a source [33,35] adapted to provide illumination in a first direction [42] and the detector [38] is adapted (I) to measure the intensity of radiation returned in a direction [38] opposite to said first direction and (ii) to accept the test object as an eye when the observed intensity is above a threshold and reject the observed object as an eye when the intensity is below the threshold.

17. A apparatus according to any one of claims 12 - 16, wherein the said second subsystem [1000] comprises

[a] a recognition pattern [39],

[b] means [41] for projecting an image of said recognition pattern onto the test object,

[c] a camera [21] adapted to capture an image of the test object including said projected image and to compare the recognition pattern with the captured pattern whereby the test object is accepted as an eye when the captured image matches the recognition pattern and rejected when the captured image does match the recognition pattern.

Fig.1.

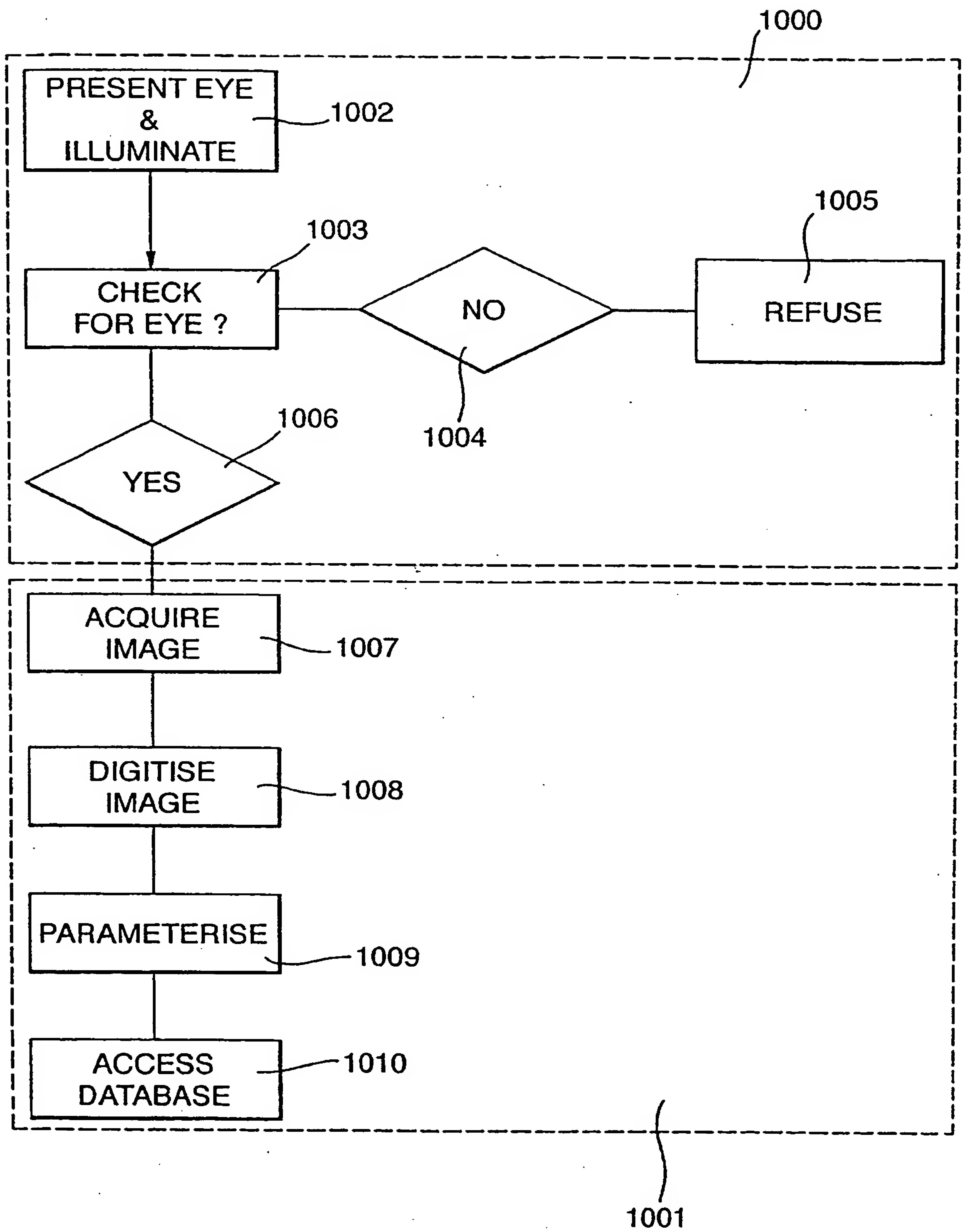

1000
PRESENT EYE & ILLUMINATE
1002
1003
CHECK FOR EYE ?
NO
1004
1005
REFUSE
1006
YES
ACQUIRE IMAGE
1007
DIGITISE IMAGE
1008
PARAMETERISE
1009
ACCESS DATABASE
1010
1001

Fig.2.

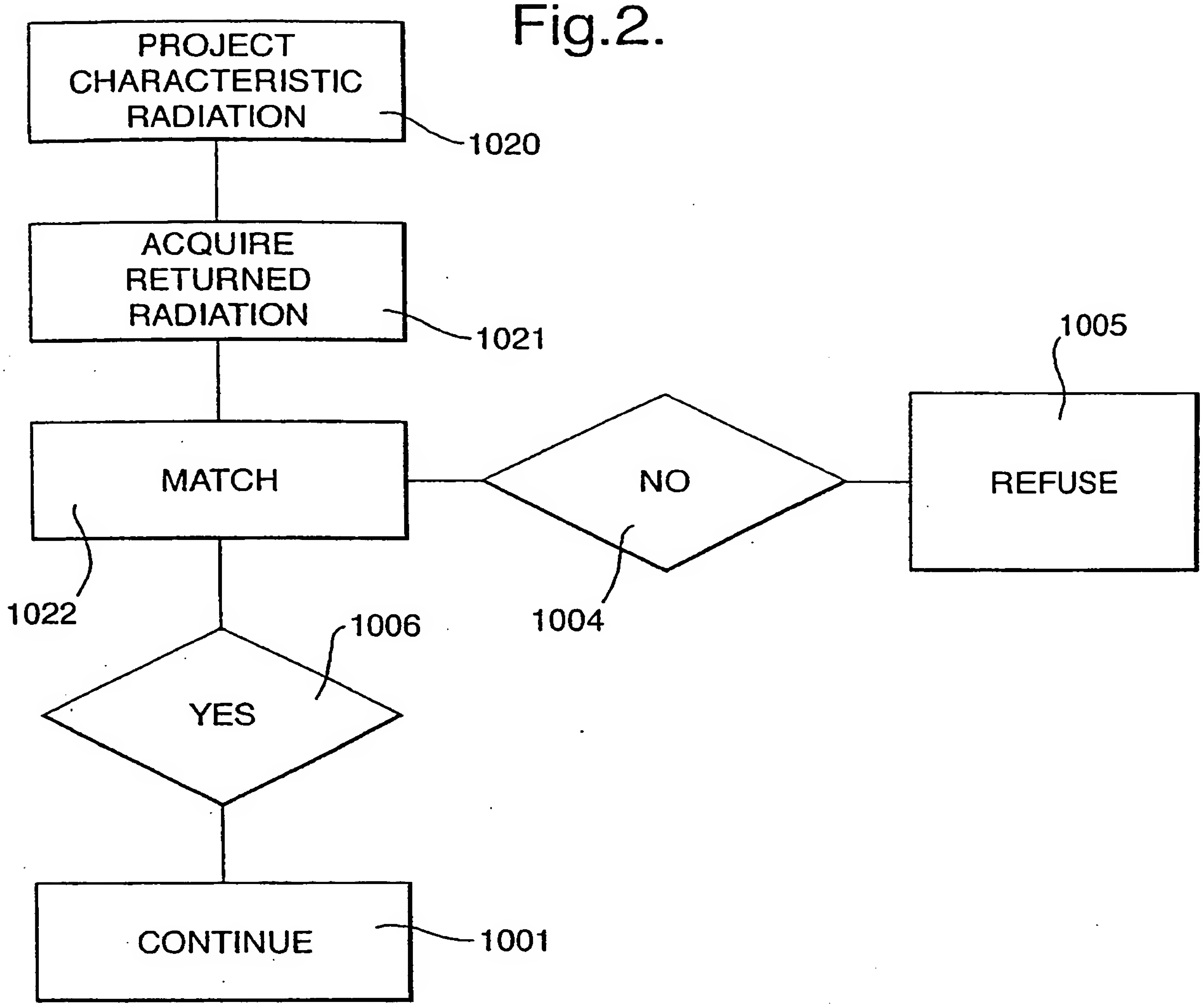

PROJECT CHARACTERISTIC RADIATION
1020
ACQUIRE RETURNED RADIATION
1021
MATCH
1022
NO
1004
REFUSE
1005
YES
1006
CONTINUE
1001

Fig.3.

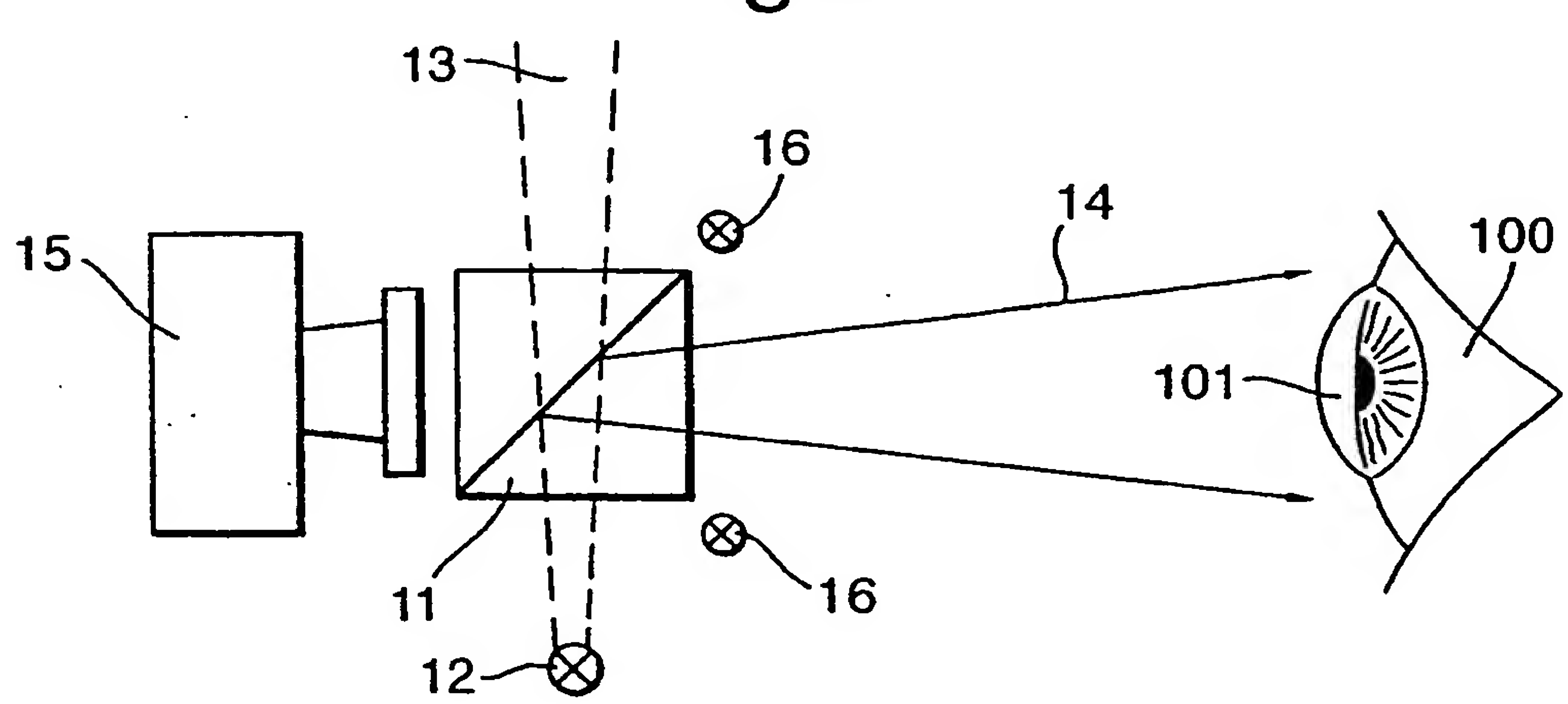
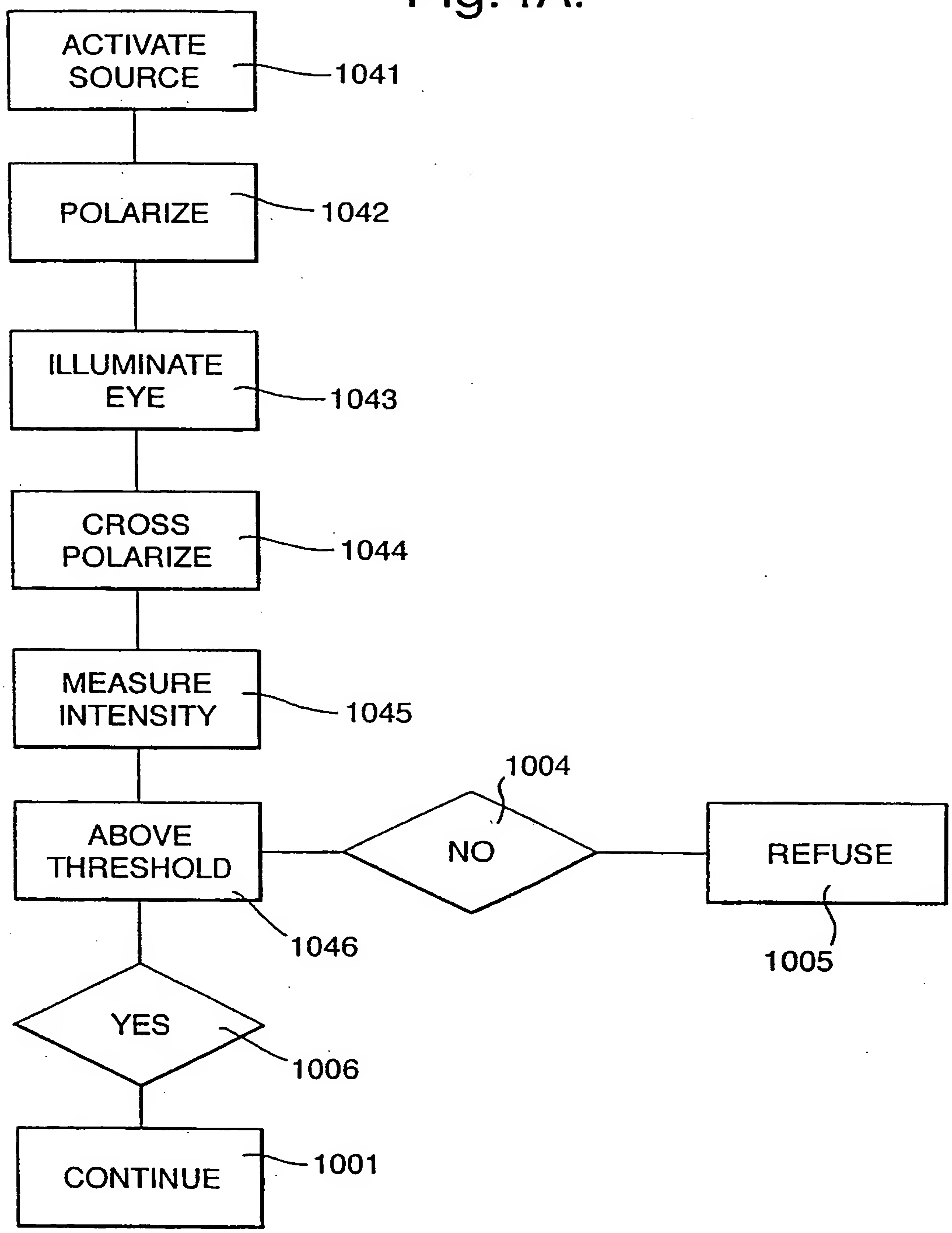

13
16
15
14
100
101
11
16
12

Fig.4A.


ACTIVATE SOURCE
1041
POLARIZE
1042
ILLUMINATE EYE
1043
CROSS POLARIZE
1044
MEASURE INTENSITY
1045
ABOVE THRESHOLD
1046
NO
1004
REFUSE
1005
YES
1006
CONTINUE
1001

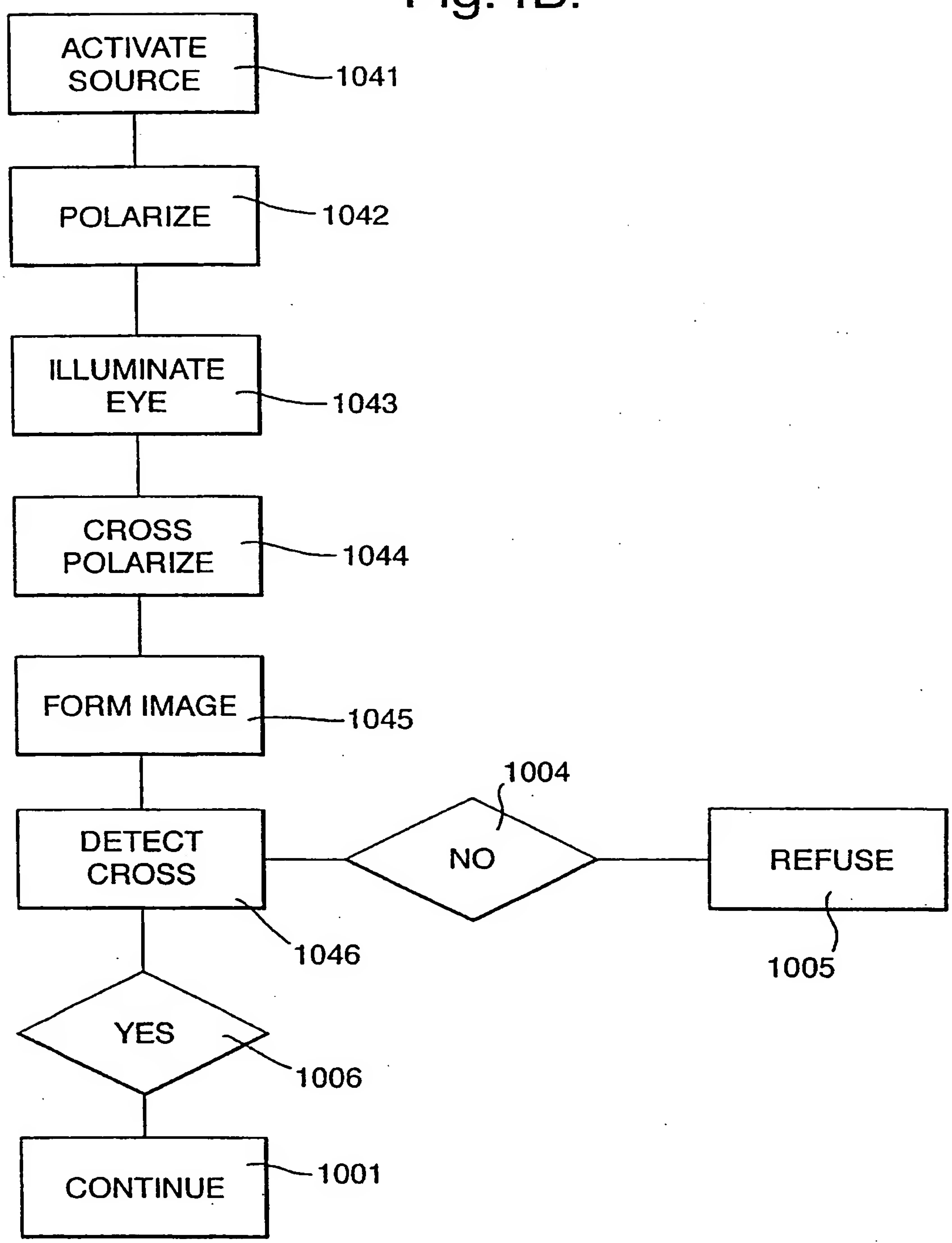

ACTIVATE SOURCE
1041
POLARIZE
1042
ILLUMINATE EYE
1043
CROSS POLARIZE
1044
FORM IMAGE
1045
1004
DETECT CROSS
NO
REFUSE
1046
1005
YES
1006
CONTINUE
1001

Fig.4B.

Fig.5.

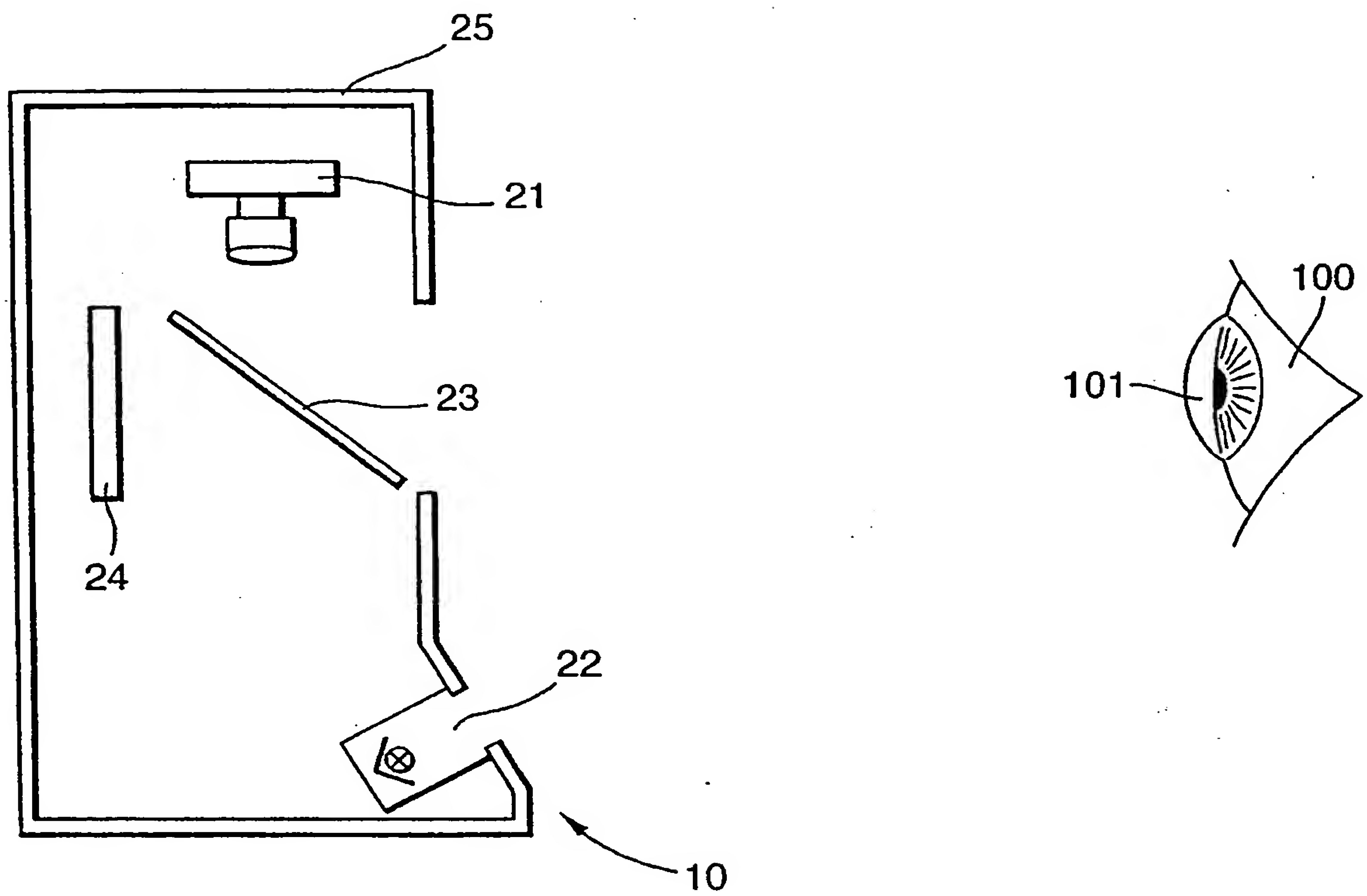


Fig.6.

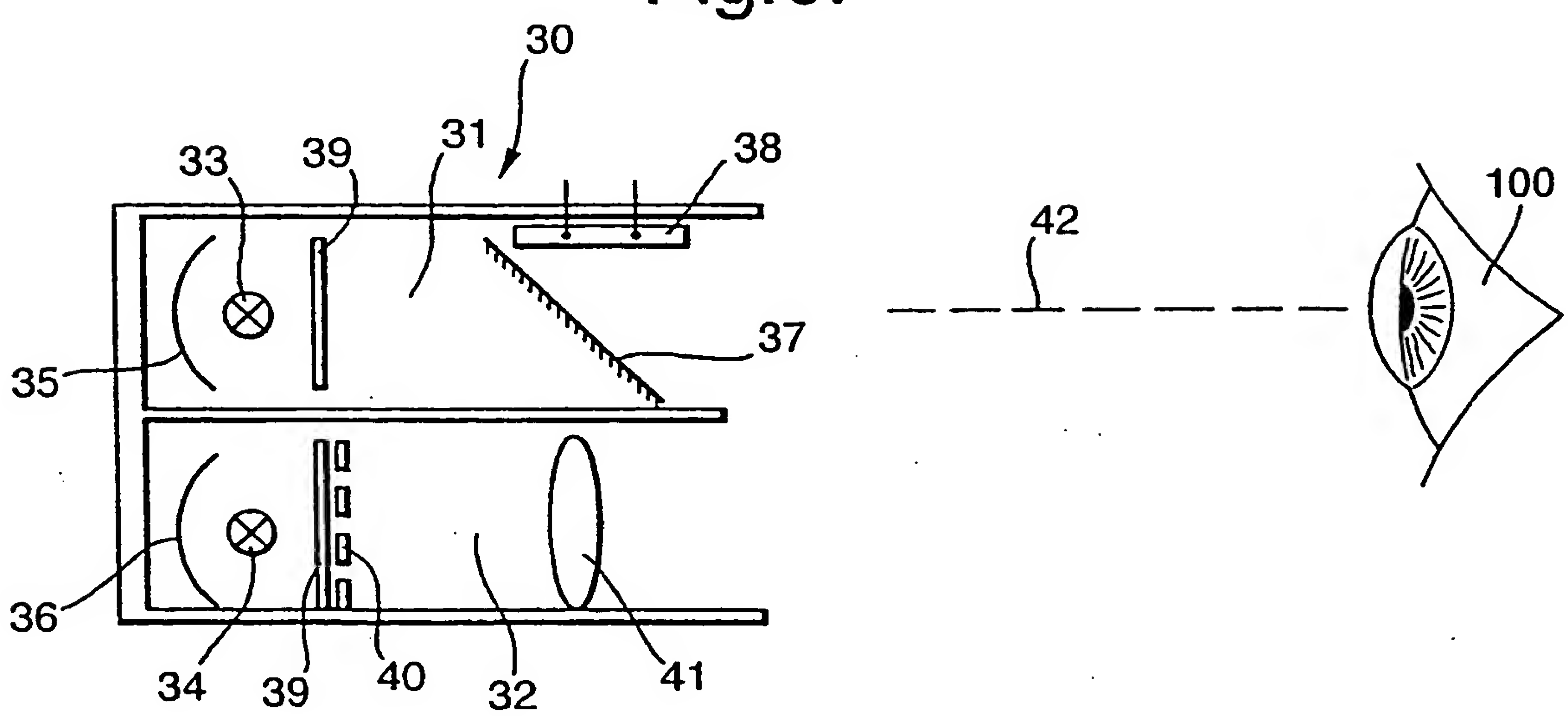


Fig.7A.

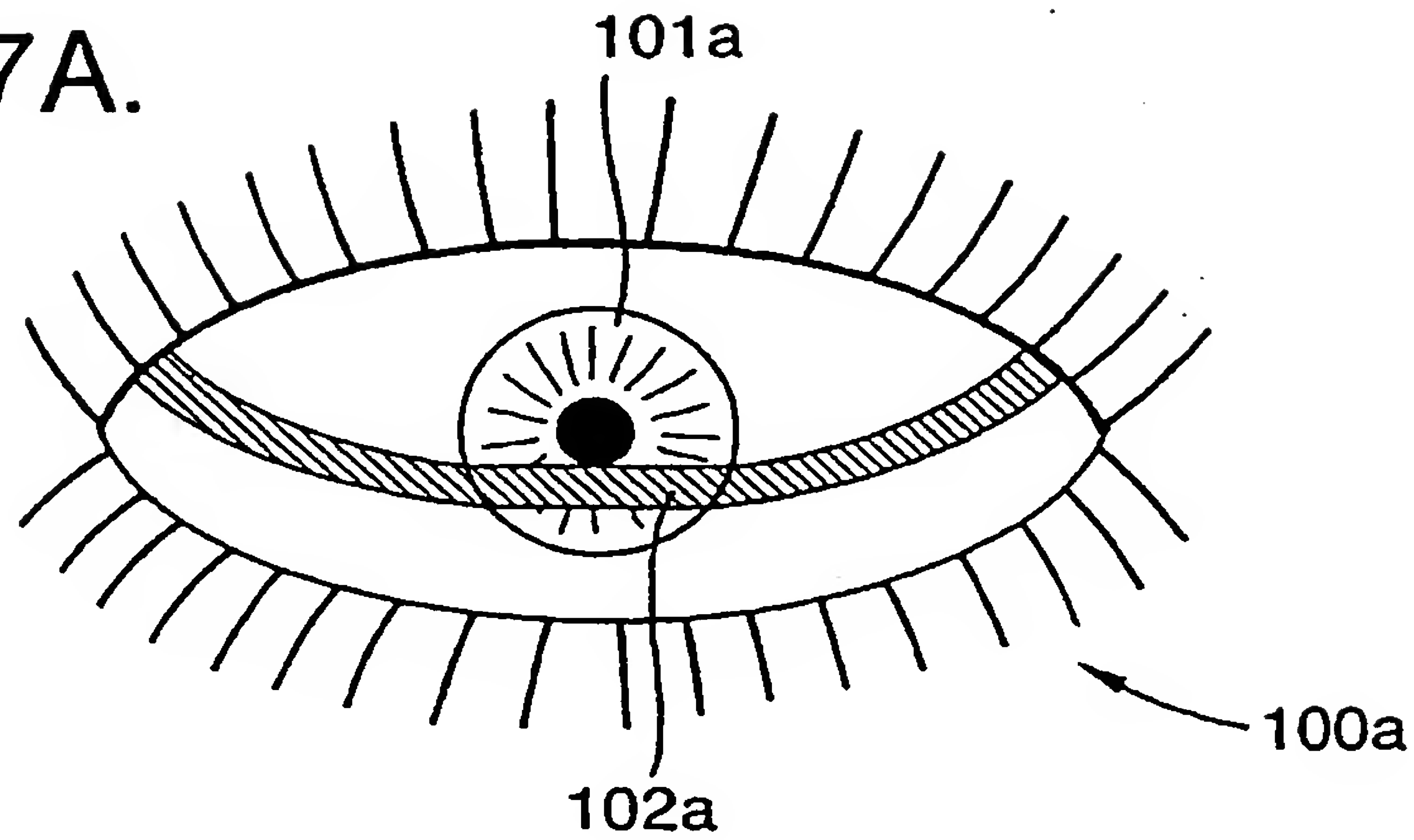


Fig.7B.

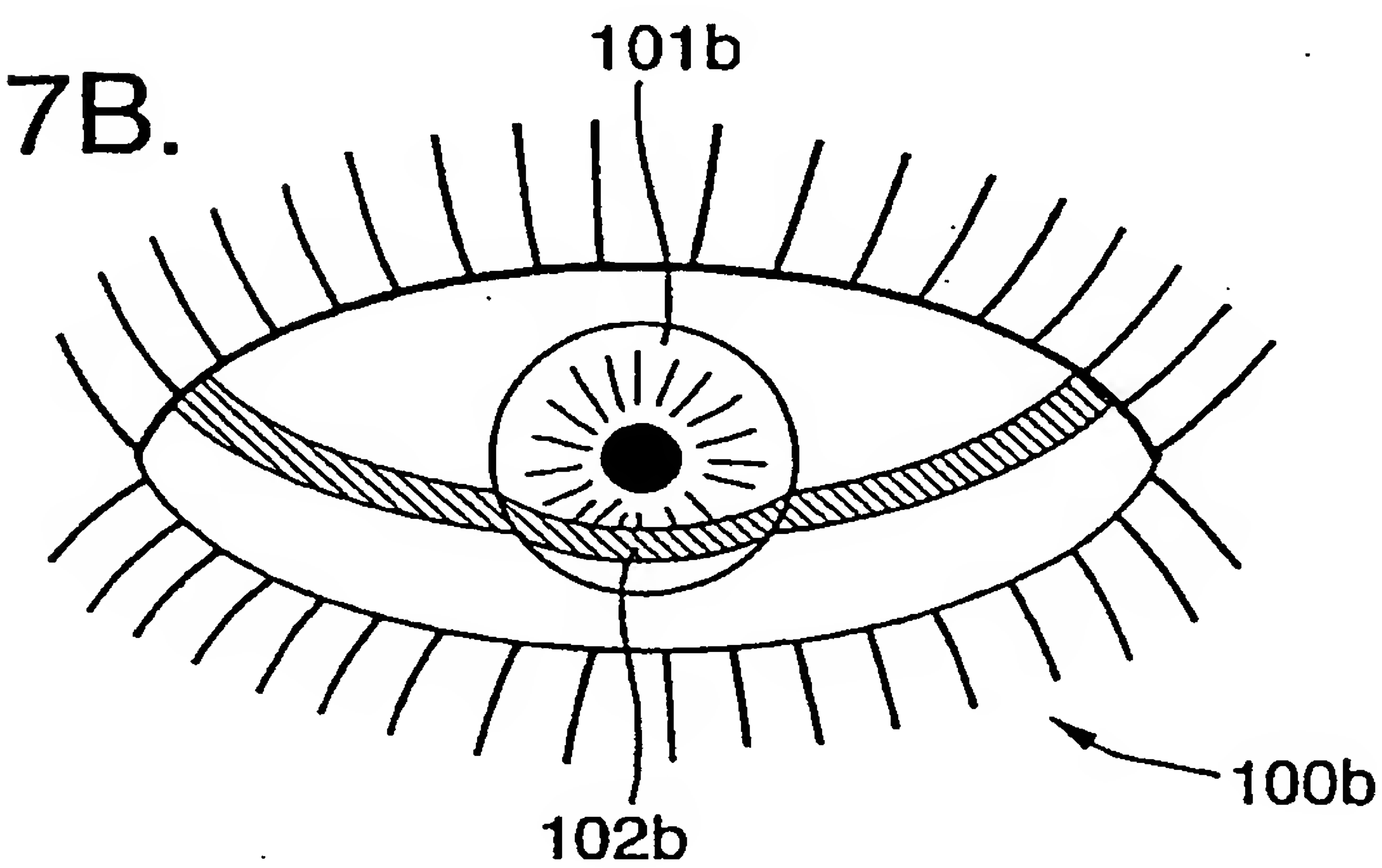
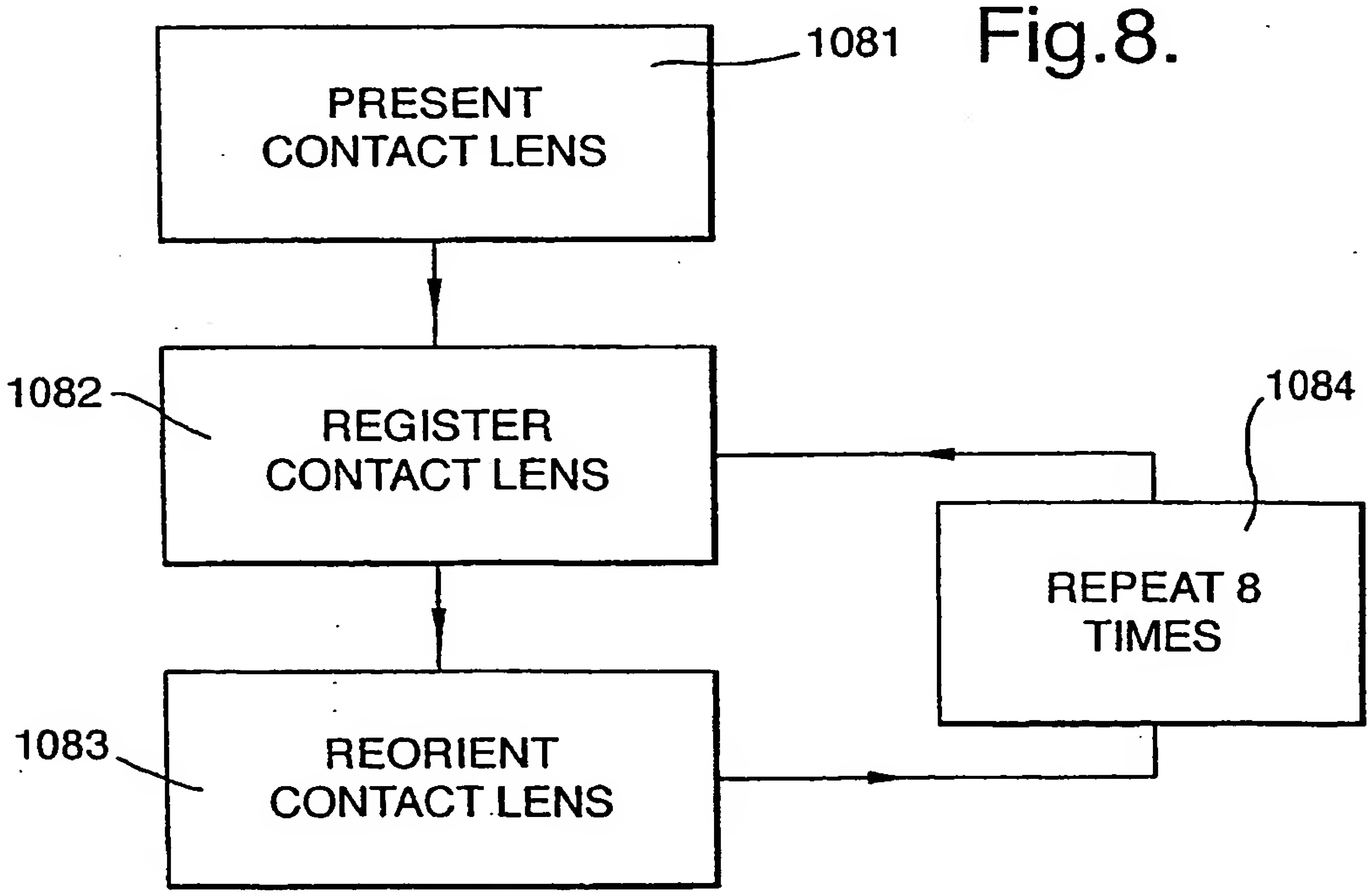


Fig.8.



INTERNATIONAL SEARCH REPORT

Inter: nal Application No
PCT/GB 00/02341

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06K9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, IBM-TDB, PAJ, EPO-Internal, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WILLIAMS G O: "IRIS RECOGNITION TECHNOLOGY" IEEE AEROSPACE AND ELECTRONIC SYSTEMS MAGAZINE,US,IEEE INC. NEW YORK, vol. 12, no. 4, page 23-29 XP000677464 ISSN: 0885-8985 P. 24 Section "Natural Protection from Artifice" ---	1-17
A	WILDES R P: "IRIS RECOGNITION: AN EMERGING BIOMETRIC TECHNOLOGY" PROCEEDINGS OF THE IEEE,US,IEEE. NEW YORK, vol. 85, no. 9, page 1348-1363 XP000738562 ISSN: 0018-9219 the whole document ---	1-17
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 August 2000	22/08/2000
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Granger, B

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/02341

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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